Impact of the Age at Menarche on Adult Body Composition in Healthy Pre- and Postmenopausal Women

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ABSTRACT The present study focuses on the impact of age at menarche on body composition development during adulthood. With 459 healthy middle-class women between 18 and 67 years (x = 41.5) the association between age at menarche and body composition was tested. Body composition, described by absolute and relative amount of fat mass, lean body mass, and bone mass, was estimated by means of dual energy x-ray absorptiometry. In order to exclude the influence of the menopausal transition on body composition, pre- and postmenopausal females were examined separately. The absolute amount of body fat was significantly lower within the group of women whose menarche occurred later. However, postmenopausal females exhibit less significant relations between the two trait systems than premenopausal women. This may be due to the impact of menopausal transition which affected the hormone levels and body composition development independently from the adolescent hormonal transition. While in both proband groups the quantitative amount of body fat was significantly related to menarcheal age, a significant relation between menarcheal age and adult body fat distribution could not be verified. Am J Phys Anthropol 105:9–20, 1998.

Several studies have focused on the complex relationship between age at menarche and body build. However, the literature regarding the association of age at menarche and adult body size is inconsistent. While some studies report a trend toward increased stature within early maturers (Dreizen et al., 1967; Onat, 1975), several other studies show a strong relationship between early menarche and increased body mass index, a higher amount of subcutaneous fat tissue, and a lower stature during early adulthood (Barker and Stone, 1936; Vikho and Apter, 1984; Garn et al., 1986; Stark et al., 1989; Malina, 1990; Wellens et al., 1992; Kirchengast and Hartmann, 1995). The so-called Frisch hypothesis or hypothesis of the critical mass, postulating the interaction between body fat and age at menarche, was first applied by Rose Frisch during the early 1970s (Frisch, 1972, 1974, 1976). Although her hypothesis met some criticism (Trusell, 1978, 1980; Scott and Johnston, 1982), several studies indicate that early maturation seems to increase overall fatness which persists throughout the reproductive years and beyond (Garn et al., 1986; Sherman et al., 1981; Ness, 1991; Kirchengast, 1993; Brown et al., 1996). Furthermore, not only the

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absolute amount of body fat is affected by the timing of maturation, but the pattern of fat distribution also varies between early and late maturers (Brown et al., 1996). However, no uniform opinion exists regarding the association between menarcheal age and fat distribution. Several authors report a strong relationship between early age at menarche and increased centripetal fat patterning up through age 65 years (Rona and Pereira, 1974; Frisancho and Flegel, 1982), whereas other studies could not verify these results (Deutsch et al., 1985; Malina and Bouchard, 1988).

In the majority of studies mentioned above, body fat and body mass were determined only by the use of body weight, body mass index, and skinfold measurements. Only a few studies (e.g., Garn, 1980) have considered the role of increasing subcutaneous fat thickness as a part of female sexual maturation and the complex changes of body build and body fat distribution induced by the menopausal transition. The impact of age at menarche on the two other major compartments of body composition, lean body mass and bone mass (bone mineral content [BMC]) have almost exclusively been restricted to the consideration of the etiology of postmenopausal osteoporosis. In the present study, we focus on the association between age at menarche and all adult body composition parameters. This includes not only body fat but also lean body mass and bone mineral content. We also test the hypothesis of Rona and Pereia (1974) and Frisancho and Flegel (1982) that a strong relationship exists between menarcheal age and adult body fat distribution.

MATERIALS AND METHODS

Subjects

The 459 female probands, aged between 18 and 67 years (x = 41.5), were examined between April 1994 and November 1995 at the Menox outpatient department clinic for treatment of the climacteric syndrome in Vienna. The examination started with quantitative determination of the serum levels of 17β-estradiol and follicle stimulating hormone (FSH). Blood samples were collected between 7.30 AM and 9.30 AM. Blood was drawn from the premenopausal probands between the eighth and tenth day of cycle (i.e., during the follicular phase before ovulation). The quantitative determination of estradiol and FSH was made at the hormone laboratory of the Menox outpatient clinic. All analyses of each subject were performed in a single assay as well as in duplicate. Serum FSH levels were determined by ENZYMUN RF. Immunoassays were done on an ES 600 automatic analyser (Böhringer Mannheim). 17β-estradiol was measured by a solid phase 125i radioimmunassay (Diagnostic Product Corporation) with an interassay variance of 7.8%. All probands were interviewed regarding their menstrual and reproductive history. The following parameters were determined: age at menarche, number of pregnancies, births, natural and induced abortions, use of oral contraceptives, regularity of menstrual cycle, length of menstrual cycle, last spontanous menstrual bleeding, age at menopause, application of hormone replacement therapy, and several socioeconomic parameters such as marital status, education, profession, profession of the husband, and place of residence. On the basis of the results of the hormone analyses and the questionnaire, the probands were divided into two groups: 181 premenopausal females between 18 and 46 years (x = 27.1) old, with regular and probably ovulatory menstrual cycles and estradiol (>25 pg/ml) and FSH (<40miV/ml) levels typical for the fertile phase of life, and 278 postmenopausal women aged between forty-four and 67 (x = 55.8) years, whose last spontaneous menstrual bleeding dated back at least 1 year prior to the present investigation and whose estradiol (<25pg/ml) and FSH (>40miV/ml) levels were typical for postmenopause.

A medical checkup (including general anamnesis, bone densiometry, EKG, and serum analyses) and the gynecological history of all females indicated that they were in apparent good health and had intact ovaries, uterus, and adrenals. None of them were on any hormonal therapy (hormone replacement therapy, hormonal contraceptives) for more than 1 year prior to the present investigation. None of the probands reported any changes in body weight as a result of the intake of hormonal contracep-

tives. None of the postmenopausal women had taken any hormone replacement therapy (estrogen/gestagen combination) up to the present study.

The postmenopausal females attended the Menox outpatient department clinic for routine checkups or for the determination of bone density for prophylactic reasons only. The premenopausal group comprised students, members of the medical staff of the Menox outpatient clinic or the University Clinic of Obstetrics and Gynecology, and volunteers.

The premenopausal and the postmenopausal group resembled each other in several socioeconomic parameters. All probands were Caucasians of Austrian origin and lived in Vienna. The analysis of the socioeconomic background indicated that all probands were members of the so-called middle class. None of them belonged to the low-income or extremely high-income class of Austria. All were well educated, having finished school and professional training. This was also true of their husbands. Differences between pre- and postmenopausal women occurred regarding marital status only: while 95% of the postmenopausal women were married, divorced, or widowed, 36% of the premenopausal women were unmarried at the time of investigation. The basis of selection for the premenopausal group was having a healthy constitution and belonging to the same social class (i.e., middle class). We decided to select only members of the middle class as probands for the present study, because members of the middle class are representative of the Austrian population and especially of the urban Austrian population.

Age at menarche

Since all probands started to menstruate more than 5 years before this study commenced, the age at menarche was determined by an interview using a retrospective method only. This technique relies on self-reported age at menarche and is reputed not to be exact. Apparently women might experience memory loss, particularly if menarche dated back to a long time ago (Chan, 1967; Bergsten-Brucefors, 1976; Cravioto et al., 1987). The limitation of retrospective methods is without doubt, especially in comparison with the status quo method and the longitudinal method. However, the adequacy of recalled age at menarche has been tested in various ways. Goodman et al. (1984) found a high degree of concordance (90%) between subjects' reported ages at menarche and perceptions of such ages as early, average, or late. Damon et al. (1969) and Roberts et al. (1986) concluded that mean age at menarche obtained with either technique is not significantly different (Bean et al., 1979; Madrigal, 1991). Furthermore, several studies yielded a reliability of 75–90% for the retrospective method (Livson and McNeill, 1962; Damon et al., 1969; Damon and Bajema, 1974; Bean et al., 1979) and concluded that the correlation between observed age at menarche and reported ages at menarche is sufficiently high for the recalled menarcheal age to be considered accurate. This should not be surprising, because menarche is a change of major physiological and psychological importance in a girl's life. As such, it should be easily recalled by young as well as by older women. According to Greif and Ulman (1982), menarche is an event remembered by the majority of women. This finding was corroborrated by the results of Colub and Catalano (1983), who found that menarche was remembered correctly by most probands independent of their chronological age. An extraordinary high percentage (98%) recalled the correct age at menarche (Pillemer et al., 1987). Given these findings, we concluded that it was reasonable to use the retrospective method. Age at menarche was defined as the chronological age at the closest birthday.

Body composition

In this study we used dual energy x-ray absorptiometry (DEXA) (Hologic Corp., Waltham, MA) (Slosman et al., 1992) to determine body composition. The body consists of soft tissue (fat and lean body mass) and bone mass. DEXA measures total-body bone mineral content, fat mass, and lean body mass with a precision (coefficient of variance) of 0.9%, 4.7%, and 1.5%, respectively. The precision for abdominal fat mass and fat % is 4.3% and 3.4%, respectively, (Svendsen et al., 1995). The extinction of

x-rays in dual energy x-ray absorptiometry is dependent on the tissue that is measured. Because absorption varies by tissue type, absolute and relative fat mass and lean body mass can be estimated. The scanner uses an x-ray source, an internal wheel to calibrate bone mineral content, and an external lucite and aluminium phantom to determine the percentage in fat of each soft-tissue sample scanned. Simultaneously with the measurement of the skeleton, the percentage of fat is determined from the ratio of attenuation of lower energy (70 kVp) to that of the higher energy (140 kVp) of the beam. This is calculated for all nonskeleton pixels scanned and extrapolated over the skeleton-containing pixels. The scan time takes less than 7 min. Radiation doses were relatively low, with 0.1 mSievert. Default software readings provided lines positioned to divide the body into six compartments: head, trunk, arms (right and left arm separately), and legs (right and left leg separately). For our study it was of special interest to divide the body into an upper body region (i.e., trunk) and a lower body region (namely the gluteal, hip and femoral region). The trunk was defined by a horizontal line below the chin, vertical lines between trunk and the arms, and a lower border formed by oblique lines passing through the colli femori. The region below the lower border of the trunk was classified as the lower body region. The upper body region includes upper body fat, typical of a more android fat pattern in the abdominal region. The lower body region contains the more gynoid fat distribution of the hip and femoral area.

The following were determined: fat mass, lean body mass, and bone mass of the whole body; fat mass, lean body mass, and bone mass of the arms; fat mass, lean body mass, and bone mass of the legs; fat mass, lean body mass, and bone mass of the trunk (i.e., upper body region); fat mass, lean body mass, and bone mass of the head; fat mass, lean body mass, and bone mass of the whole body without the head (= subtotal); fat mass, lean body mass, and bone mass of the lower body region; fat percentage of the arms, legs, trunk, head, lower body region, the whole body, and subtotal.

In addition the fat distribution index (FDI) (Kirchengast et al., 1997) was calculated as follows:

$$\text{FDI} = \text{upper body fat mass}/\text{lower body fat mass.}$$

A fat distribution index below 1 indicates a gynoid fat distribution (the fat mass of the lower body surpasses the fat mass of the upper body region). A fat distribution index above 1 defines an android fat distribution. In the latter case, the amount of the fat tissue of the upper body primarily in the abdominal region surpasses the fat mass of the lower body.

Body weight and stature were estimated according to the definitions in Knussmann (1988), and the body mass index (body weight (in kilograms)/stature squared [in meters]) was computed.

Statistical analyses

Statistical analyses were performed with SPSS for Windows (Microsoft Corp., Redmond, WA) (Bühl and Zöfel, 1996). Kolmogoroff-Smirnov tests indicated that the normal distribution of the body composition variables could not be assumed. After computing descriptive statistics (means, standard deviations, medians, range) we normalized all variables by computing z-scores. Group differences regarding age at menarche and body composition variables between pre- and postmenopausal females were tested by means of the Student's *t*-tests. Duncan tests were applied to test the significance of body composition group differences between females with an extremely early menarche, females with a moderate age at menarche, and females with a late menarche. To obtain more information about the structure of the body composition data and to reduce the number of variables, we undertook factor analyses (principal component methods, varimax rotation) (Bühl and Zöfel, 1996) on all body composition variables and separately for pre- and postmenopausal women. Individual facor scores were determined and correlated with the age at menarche.

TABLE 1. Sample parameters and t-values of body composition variables[1]

Variable	Premenopausal x	Premenopausal SD	Postmenopausal x	Postmenopausal SD	t-value	
Total fat mass	26.6	13.9	32.7	9.8	−5.14	$P < 0.001$
Head fat mass	0.8	0.2	0.9	0.1	−3.42	$P < 0.01$
Subtotal fat mass	26.1	14.1	31.8	9.7	−4.71	$P < 0.001$
Right arm fat mass	1.5	0.8	1.9	0.8	−5.86	$P < 0.001$
Left arm fat mass	1.5	0.9	1.9	0.6	−4.40	$P < 0.001$
Trunk fat mass	11.4	8.3	15.9	6.7	−6.07	$P < 0.001$
Right leg fat mass	5.8	2.3	6.3	1.9	−2.35	$P < 0.05$
Left leg fat mass	5.6	2.3	6.1	1.9	−2.20	$P < 0.05$
Lower body fat mass	11.5	4.4	12.8	4.0	−2.23	$P < 0.05$
Total lean mass	40.1	4.9	40.5	4.9	−0.93	n.s.
Head lean mass	3.1	0.3	3.2	0.3	−1.29	n.s.
Subtotal lean mass	37.1	4.7	37.4	4.4	−0.56	n.s.
Right arm lean mass	1.7	0.3	1.7	0.3	0.09	n.s.
Left arm lean mass	1.4	0.3	1.4	0.3	0.82	n.s.
Trunk lean mass	21.0	2.4	21.4	2.3	−1.69	n.s.
Right leg lean mass	6.6	1.1	6.5	1.0	0.87	n.s.
Left leg lean mass	6.4	1.1	6.3	0.9	0.19	n.s.
Total bone mass	2.3	0.3	2.2	0.3	1.30	n.s.
Head bone mass	0.5	0.1	0.5	0.1	1.24	n.s.
Subtotal bone mass	1.8	0.3	1.7	0.3	1.14	n.s.
Right leg bone mass	0.5	0.1	0.4	0.1	1.89	n.s.
Left leg bone mass	0.4	0.1	0.4	0.1	1.39	n.s.
Trunk bone mass	0.7	0.1	0.6	0.1	1.30	n.s.
Right arm bone mass	0.1	0.1	0.1	0.0	−1.20	n.s.
Left arm bone mass	0.1	0.1	0.1	0.0	−0.41	n.s.
Fat distribution index	0.8	0.4	1.3	0.5	−9.77	$P < 0.0001$
Stature	165.8	6.1	164.3	5.6	2.73	$P < 0.01$
Body weight	64.1	15.6	74.5	13.5	−4.59	$P < 0.001$
Body mass index	23.2	6.1	28.4	5.7	−5.57	$P < 0.001$
Total fat %	36.2	10.9	42.6	6.7	−7.11	$P < 0.001$
Head fat %	18.2	1.2	19.1	2.7	−4.94	$P < 0.001$
Subtotal fat %	37.6	11.3	44.2	6.8	−7.05	$P < 0.001$
Right arm fat %	42.0	13.5	50.1	8.2	−7.22	$P < 0.001$
Left arm fat %	47.1	12.3	54.1	7.8	−6.80	$P < 0.001$
Trunk fat %	31.0	14.3	40.3	9.5	−7.71	$P < 0.001$
Right leg fat %	43.8	8.7	46.9	6.1	−4.32	$P < 0.001$
Left leg fat %	43.9	8.5	46.7	6.0	−3.91	$P < 0.001$

[1]x, means; SD, standard deviation; t-values. Stature is in centimeters; body weight and body composition variables are in kilograms.

RESULTS

Age at menarche

Within the premenopausal group, menarche occurred at the age of 13.0 (SD = 1.7) years on average. The postmenopausal females showed a very similar mean age at menarche: x = 13.1 (SD = 1.7).

In 109 postmenopausal females (39.2%), menarche occurred relatively early, before the twelfth birthday. In the total postmenopausal group, 123 females (44.4%) experienced their first menstrual bleeding between their twelfth and fourteenth birthday, and 46 females (16.4%) experienced a relatively late menarche, after their fourteenth birthday. Quite different age at menarche patterns are observed in the premenopausal proband group. The great majority (n = 120; 66.4%) started to menstruate between their twelfth and fourteenth birthday. However, in 36 females (19.9%) of this proband group, menarche occurred before their twelfth birthday, and only 25 females (13.7%) experienced their first menstrual bleeding after their fourteenth birthday.

Body composition

As shown in Table 1, the absolute and relative amount of body fat, fat distribution index, body mass index, body weight, and stature differed significantly between pre- and postmenopausal females. Postmenopausal women were significantly heavier but shorter than premenopausal women and surpassed the premenopausal females in all variables pertaining to the absolute and relative amount of body fat and the fat distribution index. With the exception of

TABLE 2. Factor analyses, loadings, eigenvalues, percentage of variance[1]

Variable	Premenopausal F1	Premenopausal F2	Premenopausal F3	Premenopausal F4	Premenopausal F5	Postmenopausal F1	Postmenopausal F2	Postmenopausal F3	Postmenopausal F4
Right arm FM	0.91	0.08	0.06	0.10	0.30	0.88	0.09	0.19	0.12
Left arm FM	0.74	−0.06	−0.01	0.27	0.52	0.85	0.14	0.86	0.09
Trunk FM	0.92	0.23	0.12	0.02	−0.02	0.86	−0.03	0.17	0.23
Right leg FM	0.87	0.27	0.23	−0.20	0.02	0.81	0.23	0.17	−0.05
Left leg FM	0.88	0.29	0.22	−0.19	0.01	0.80	0.22	0.19	−0.06
Subtotal FM	0.95	0.21	0.09	0.00	0.17	0.95	0.07	0.19	0.14
Head FM	0.31	0.13	−0.09	0.15	0.87	0.33	0.07	0.22	0.88
Total FM	0.94	0.24	0.17	−0.04	−0.01	0.95	0.07	0.19	0.15
Right arm LM	−0.12	0.55	0.13	0.69	0.09	0.06	0.15	0.72	0.12
Left arm LM	−0.18	0.41	0.12	0.80	0.07	0.09	0.17	0.67	0.06
Trunk LM	0.08	0.79	0.29	0.19	0.21	0.16	0.35	0.80	0.08
Right leg LM	0.36	0.85	0.19	0.08	−0.00	0.34	0.28	0.82	0.15
Left leg LM	0.35	0.86	0.18	0.07	−0.00	0.34	0.29	0.80	0.17
Subtotal LM	0.20	0.89	0.26	0.24	0.13	0.24	0.34	0.88	0.13
Head LM	0.22	0.35	0.25	0.07	0.53	0.15	0.12	0.27	0.91
Total LM	0.22	0.86	0.27	0.21	0.17	0.24	0.31	0.84	0.18
Right arm BM	0.46	0.32	0.59	0.41	0.06	0.35	0.67	0.33	0.01
Left arm BM	0.11	−0.04	0.62	0.60	0.13	0.08	0.62	0.12	−0.01
Trunk BM	0.22	0.40	0.70	0.19	0.06	0.17	0.73	0.27	0.08
Right leg BM	0.27	0.60	0.64	0.06	0.05	0.14	0.84	0.36	−0.02
Left leg BM	0.25	0.61	0.63	0.01	0.07	0.12	0.84	0.33	−0.02
Subtotal BM	0.29	0.52	0.74	0.20	0.09	0.9	0.89	0.34	0.02
Head BM	−0.34	0.02	0.58	−0.12	0.49	−0.26	0.68	0.12	0.38
Total BM	0.10	0.46	0.85	0.06	−0.12	0.09	0.94	0.26	0.12
Transformation matrix									
Factor 1	0.57	0.63	0.46	0.19	0.18	0.54	0.55	0.59	0.19
Factor 2	−0.79	0.37	0.35	0.33	−0.04	0.79	−0.54	−0.19	0.06
Factor 3	−0.00	−0.32	−0.09	0.53	0.78	0.24	0.61	−0.62	−0.34
Factor 4	0.01	−0.54	0.81	−0.22	0.02	−0.07	0.15	−0.34	0.92
Factor 5	−0.22	0.27	−0.03	−0.72	0.59				
Eigenvalue	12.05	4.40	1.87	1.57	1.09	11.35	4.32	2.21	1.53
% of variance	50.2	18.3	7.8	6.6	4.5	47.3	18.0	9.2	6.4

[1] BM, bone mass; FM, fat mass; LM, lean mass; F, factor.

muscle mass in both arms, postmenopausal females appeared to have higher values of lean body mass, although the group differences were not statistically significant. The premenopausal probands also surpassed the postmenopausal ones in all bone mass parameters and in stature.

Factor analyses

Factor analyses computed on the basis of all body composition variables yielded five factors with an eigenvalue above 1.0 for the premenopausal proband group and four factors with an eigenvalue above 1.0 for the postmenopausal proband group (Table 2). The first factor (eigenvalues 12.05 and 11.35) can be described as a body fat factor for both groups. Highest loadings (0.74–0.95) were found for body fat variables exclusively. The second factor (eigenvalues 4.40–4.32) differed between the two proband groups. Within the premenopausal proband group, the second factor can be interpreted as a lean body mass factor, because highest loadings (0.79–0.89) were found for those variables which describe the lean body mass. In contrast, within the postmenopausal proband group, the second factor can be described as a bone mass factor, because highest loadings (0.62–0.94) were found for variables describing bone mass exclusively. The third factor (eigenvalues 2.21 and 1.87) differed between the both proband groups again. While within the premenopausal group factor three can be named bone mass factor with higher loadings (0.58–0.85) for bone mass variables, within the postmenopausal group the third factor can be classified as a lean body mass factor with higher loadings (0.56–0.88) for lean body mass variables. The fourth factor (eigenvalues 1.57 and 1.53) differed between the two proband groups, too. In the premenopausal group, factor four can be interpreted as an arm muscle factor with higher loadings (0.69–0.80) for the lean body mass of both arms. In

TABLE 3. Body fat and age at menarche, Duncan analyses[1]

	Age at menarche							
	<12 years		12–14 years		>14 years			
Variable	x	SD	x	SD	x	SD	F-value	
Premenopausal	(n = 36)		(n = 120)		(n = 25)			
Right arm FM	1.9	1.1[3,4]	1.4	0.7[2]	1.5	1.0[2]	3.7	$P < 0.05$
Left arm FM	1.9	0.9[3,4]	1.4	0.6[2,4]	1.7	1.0[2,3]	2.7	$P < 0.05$
Trunk FM	16.0	10.1[3,4]	10.6	8.0[2,4]	9.7	7.2[2]	3.3	$P < 0.05$
Right leg FM	6.8	2.4[3,4]	5.7	2.3[2,4]	5.1	2.5[2,3]	3.0	$P < 0.05$
Left leg FM	6.8	2.3[3,4]	5.5	2.2[2,4]	4.9	2.4[2,3]	3.1	$P < 0.05$
Lower body FM	13.7	3.9[2,3]	11.3	3.1[2,4]	10.0	2.6[2,3]	3.3	$P < 0.05$
Subtotal FM	33.6	16.7[3,4]	24.7	13.3	24.8	15.3[2]	3.2	$P < 0.05$
Head FM	0.8	0.1	0.8	0.1	0.9	0.4	1.0	n.s.
Total FM	34.1	16.4[3,4]	25.4	13.5[2,4]	23.1	12.8[3,4]	3.3	$P < 0.05$
Right arm fat %	47.0	12.8	41.4	13.4	38.4	13.1	1.9	n.s.
Left arm fat %	51.6	10.3	46.2	12.1	43.2	11.8	2.2	n.s.
Trunk fat %	37.9	15.8[3,4]	29.6	14.1[2]	27.7	13.5[2]	3.6	$P < 0.05$
Right leg fat %	46.9	7.7[3,4]	43.6	8.4[2,3]	39.1	10.7[2,3]	3.7	$P < 0.05$
Left leg fat %	47.4	7.2[3,4]	43.6	8.4[2,3]	39.7	10.6[3,4]	3.5	$P < 0.05$
Subtotal fat %	42.8	11.6[3,4]	36.9	11.1[2,3]	33.6	11.7[2,3]	3.1	$P < 0.05$
Head fat %	18.5	0.7	18.2	1.3	18.1	0.9	0.5	n.s.
Total fat %	41.5	11.2[3,4]	35.5	10.6[2,3]	31.2	11.4[2,3]	4.2	$P < 0.01$
Postmenopausal	(n = 109)		(n = 123)		(n = 46)			
Right arm FM	2.1	0.7	1.9	0.6	1.9	0.8	1.5	n.s.
Left arm FM	1.9	0.5	1.8	0.5	1.8	0.6	0.5	n.s.
Trunk FM	17.4	7.4	15.5	5.9	15.0	6.6	1.7	n.s.
Right leg FM	6.7	2.3[4]	6.5	1.9	6.0	1.4[2]	3.5	$P < 0.05$
Left leg FM	6.5	2.2[4]	6.3	1.9	5.8	1.3[2]	3.8	$P < 0.05$
Lower Body FM	13.2	3.9[4]	12.9	3.2	11.9	3.1[2]	3.8	$P < 0.05$
Subtotal FM	34.6	12.1	31.5	10.8	30.9	8.3	2.2	n.s.
Head FM	0.9	0.1	0.8	0.1	0.9	0.1	2.1	n.s.
Total FM	36.3	12.0[3,4]	32.4	10.9[2,4]	31.7	8.3[2,3]	3.5	$P < 0.05$
Right arm fat %	52.3	8.2	49.3	7.9	49.4	9.5	2.3	n.s.
Left arm fat %	56.3	8.2	53.7	7.6	53.7	7.9	1.7	n.s.
Trunk fat %	42.5	9.8[4]	40.1	9.5	38.7	9.9[2]	3.4	$P < 0.05$
Right leg fat %	48.9	6.4[3]	46.4	5.4[2]	47.5	6.2	3.1	$P < 0.05$
Left leg fat %	48.2	6.2[3]	46.0	5.2[2]	47.4	6.8	2.9	$P < 0.05$
Subtotal fat %	46.4	2.5	43.8	6.4	43.5	7.5	2.5	n.s.
Head fat %	19.2	0.9	18.8	0.9	19.1	1.7	2.1	n.s.
Total fat %	44.9	6.6[3,4]	42.2	6.2[2]	41.9	7.2	3.4	$P < 0.05$

[1] Fat mass given in kilograms. FM, fat mass.
[2] Significantly different from early maturers.
[3] Significantly different from moderate maturers.
[4] Significantly different from late maturers.

the postmenopausal group, factor four is a head factor with higher loadings (0.69–0.80) for the lean mass and the fat mass of the head. The premenopausal group yielded a fifth factor (eigenvalue 1.09) which resembled the fourth factor of the postmenopausal group, because higher loadings (0.53–0.87) occurred for the lean and fat mass of the head exclusively (see Table 2).

Age at menarche and body fat

In premenopausal women, nearly all parameters describing the absolute and relative amount of body fat mass were significantly lower for women with a higher age at menarche. Insignificant differences between early, moderate, and late maturers were found for absolute and relative head fat mass and the relative amount of fat mass at the arms only (Table 3).

Within the postmenopausal group, an identical trend could be observed; however, not all of the stated differences between early, moderate, and late maturers were of statistical significance (Table 3).

Age at menarche and lean body mass

Regarding the association patterns between lean body mass and age at menarche, no significant differences among early, moderate, and late maturers occurred for premenopausal and for postmenopausal women. Nevertheless, females, whose menarche occurred between their twelfth and fourteenth

TABLE 4. Lean body mass and age at menarche, Duncan analyses[1]

Variable	Age at menarche <12 years x	SD	12–14 years x	SD	>14 years x	SD	F-value	
Premenopausal	(n = 36)		(n = 120)		(n = 25)			
Right arm FM	1.8	0.3	1.7	0.3	1.8	0.3	1.9	n.s.
Left arm LM	1.5	0.3	1.4	0.3	1.5	0.3	1.3	n.s.
Trunk LM	21.1	1.9	20.9	2.5	21.1	2.6	0.2	n.s.
Right leg LM	6.9	1.3	6.5	1.1	6.8	1.4	1.2	n.s.
Left leg LM	6.7	1.4	6.3	1.1	6.5	1.3	0.9	n.s.
Subtotal LM	38.1	4.5	36.8	4.6	37.7	5.3	0.7	n.s.
Head LM	3.1	0.3	3.1	0.3	3.0	0.3	0.8	n.s.
Total LM	41.1	4.8	39.7	4.8	40.8	5.5	0.9	n.s.
Postmenopausal	(n = 109)		(n = 123)		(n = 46)			
Right arm LM	1.6	0.3	1.7	0.3	1.8	0.3	1.7	n.s.
Left arm LM	1.3	0.3	1.4	0.2	1.4	0.3	0.9	n.s.
Trunk LM	21.3	2.7	21.2	2.2	21.5	1.9	0.3	n.s.
Right leg LM	6.4	1.0	6.4	0.9	6.5	1.1	0.2	n.s.
Left leg LM	6.4	1.0	6.3	0.9	6.3	0.9	1.0	n.s.
Subtotal LM	37.1	4.7	36.9	4.1	37.4	4.0	0.2	n.s.
Head LM	3.3	0.3	3.2	0.3	3.3	0.4	1.4	n.s.
Total LM	40.4	4.9	40.1	4.2	40.8	3.9	0.5	n.s.

[1] Lean mass given in kilograms. FM = fat mass; LM = lean mass.

TABLE 5. Bone mass and age at menarche, Duncan analyses[1]

Variable	Age at menarche <12 years x	SD	12–14 years x	SD	>14 years x	SD	F-value	
Premenopausal	(n = 36)		(n = 120)		(n = 25)			
Right arm BM	0.2	0.1	0.1	0.0	0.1	0.0	2.1	n.s.
Left arm BM	0.1	0.0	0.1	0.0	0.1	0.0	1.3	n.s.
Trunk BM	0.7	0.1	0.6	0.1	0.6	0.1	2.3	n.s.
Right leg BM	0.5	0.1	0.5	0.1	0.5	0.1	1.0	n.s.
Left leg BM	0.5	0.1	0.4	0.1	0.4	0.1	0.5	n.s.
Subtotal BM	1.9	0.3	1.8	0.3	1.8	0.3	1.9	n.s.
Head BM	0.5	0.1	0.5	0.1	0.5	0.1	0.2	n.s.
Total BM	2.5	0.4	2.3	0.3	2.2	0.6	1.8	n.s.
Postmenopausal	(n = 109)		(n = 123)		(n = 46)			
Right arm BM	0.1	0.0	0.1	0.0	0.1	0.0	0.7	n.s.
Left arm BM	0.1	0.0	0.1	0.0	0.1	0.0	0.9	n.s.
Trunk BM	0.6	0.1	0.6	0.1	0.6	0.1	1.3	n.s.
Right leg BM	0.4	0.1	0.4	0.1	0.4	0.1	1.1	n.s.
Left leg BM	0.4	0.1	0.4	0.1	0.4	0.1	0.7	n.s.
Subtotal BM	1.8	0.3	1.8	0.2	1.7	0.2	2.5	n.s.
Head BM	0.4	0.1	0.5	0.1	0.5	0.1	1.3	n.s.
Total BM	2.1	0.3	2.2	0.3	2.2	0.3	2.5	n.s.

[1] Bone mass given in kilograms. BM = bone mass.

birthday showed the lowest values of lean body mass in both proband groups (Table 4).

Age at menarche and bony tissue

No significant relationships could be determined for menarcheal age on adult bone mass. In the premenopausal group, early maturers seem to have a higher absolute amount of bone mass than moderate or late maturers. In apparent contrast, in postmenpausal females early maturers seem to exhibit a lower bone mass than moderate and late maturers. Unfortunately, in both groups these relations were statistically insignificant (Table 5).

Anthropometric variables and age at menarche

Early maturers in our study were generally shorter but heavier than moderate and late maturers. This is true for both proband groups. However, we found important differences between the two proband groups occurred. In premenopausal females, the gen-

TABLE 6. Anthropometric variables and age at menarche, Duncan analyses

Variable	Age at menarche <12 years x	SD	12–14 years x	SD	>14 years x	SD	F-value	
Premenopausal	(n = 36)		(n = 120)		(n = 25)			
Stature (cm)	163.9	6.6	166.0	5.7	167.1	7.7	0.9	n.s.
Body weight (kg)	77.3	21.4[2,3]	66.5	15.8[1]	65.0	15.8[1]	3.5	$P < 0.05$
Fat distribution index	0.8	0.4	0.8	0.4	0.9	2.4	1.9	n.s.
Body mass index	27.1	7.2[2,3]	24.3	6.2[1,3]	22.2	4.6[1,2]	5.1	$P < 0.01$
Postmenopausal	(n = 109)		(n = 123)		(n = 46)			
Stature (cm)	162.1	5.7[2,3]	164.7	5.3[1]	165.1	5.1[1]	4.5	$P < 0.05$
Body weight (kg)	76.1	14.7	73.2	10.5	74.2	12.9	0.9	n.s.
Fat distribution index	1.3	0.5	1.3	0.5	1.2	0.4	1.2	n.s.
Body mass index	29.2	6.5	27.3	4.5	27.3	4.3	1.5	n.s.

[1] Significantly different from early maturers.
[2] Significantly different from moderate maturers.
[3] Significantly different from late maturers.

eral trend led to significant differences among early, moderate, and late maturers in body weight and the body mass index but not in stature and fat distribution. In contrast, in postmenopausal females only stature differed significantly among early, moderate, and late maturers. No significant differences among early, moderate, and late maturers could be observed in android vs. gynoid fat distribution for both proband groups (Table 6).

TABLE 7. Partial correlations (chronological age = constant) between body composition factor scores and age at menarche

Factor		Rho	
Premenopausal			
Body fat factor	(F1)	−0.24	($P < 0.01$)
Lean mass factor	(F2)	−0.03	n.s.
Bone mass factor	(F3)	−0.21	($P < 0.05$)
Arm muscle factor	(F4)	0.01	n.s.
Head factor	(F5)	0.02	n.s.
Postmenopausal			
Body fat factor	(F1)	−0.19	($P < 0.05$)
Bone mass factor	(F2)	−0.17	($P < 0.05$)
Lean mass factor	(F3)	−0.01	n.s.
Head factor	(F4)	−0.02	n.s.

Correlations between age at menarche and individual factor scores

The correlations between the individual factor scores and age at menarche yielded significant negative relations between age at menarche and the body fat factor: the later menarche occurred, the lower was body fat mass during adulthood. This association pattern corroborrated the results of Duncan analyses and was true for females during the premenopausal as well as during the postmenopausal phase of life. For bone mass, the results of the correlations with age at menarche did not reflect the results of Duncan analyses, which yielded no significant differences in bone mass among early, moderate, and late maturers for premenopausal as well as for postmenopausal women: The bone mass factor of the premenopausal as well as of the postmenopausal proband group correlated negatively with the age at menarche. The earlier women started to menstruate, the higher was their bone mass during adulthood. For lean body mass factors, the head factors, and the arm muscle factor, no correlation with the age at menarche was observed (Table 7).

DISCUSSION

The findings of the present study corroborrate the results of several previous research teams (Garn et al., 1986; Ness, 1991; Wellens et al., 1992) which describe shorter statures and higher body weight, body mass indices and a higher amount of fat tissue during adulthood in early-maturing females than in later-maturing females. The hypothesis that early maturation is associated with increased stature (Dreizen et al., 1967; Onat, 1975) could not be verified. Beside the significant relationship between body fat and age at menarche throughout adult life, no significant association patterns between menarcheal age and the other body composition components, lean body mass, and bone mass, could be shown by means of Duncan analyses. However, a significantly negative correlation between the bone mass factor and the

age at menarche was found for premenopausal as well as postmenopausal females. Nevertheless, the correlations between bone mass factor and menarcheal age are rather low ($P < 0.05$), and therefore we conclude that body fat is the main body composition component which is significantly associated with maturation time throughout adult life.

The onset of menstrual bleeding is triggered by characteristic hormonal changes during late childhood and early puberty. Increased adrenal androgen levels influence the hypothalamus and induce the secretion of gonadotropin-releasing hormone which stimulates the release of the gonadotropines FSH and lutenizing hormone (LH) in the pituitary gland. The increased gonadotropin levels stimulate estradiol production and secretion by the ovaries. When gonadotropin and estradiol secretion reach a distinct level, they induce the onset of menarcheal bleeding (Kuhlmann and Straub, 1986). The subcutaneous fat tissue acts as a so-called secondary hormonal gland, because steroid hormone synthesis takes place there. Estrogens are synthetized in subcutaneous fat by aromatization from androgens (Perel and Killinger, 1979; Kirschner et al., 1982). However, not only body fat tissue influences hormone synthesis, for the sex steroids are also responsible for the development of body fat tissue and the expression of the sex-type-specific body fat distribution (Tanner, 1962). The development of lower body fat, namely fat deposits at the femoral-gluteal region and at the hips, is under the control of estrogens and progesterone (Rebuffe-Scrive et al., 1985, 1986; Björntrop, 1987; Freedman et al., 1990). During the fertile phase of life, the adipocytes of this lower body region show increased lipoprotein lipase activity and a blunted lipolytic response in comparison to the abdominal adipocytes. At the abdominal region, estradiol induces lipolysis. Age and primarily menopause-dependent hormonal alterations disturb this interaction. Diminished estradiol levels reduce the lipolytic activity of abdominal adipocytes and lead to increased abdominal and overall fat deposits during postmenopause (Rebuffe-Scrive et al., 1985, 1986; Björntrop, 1987; Freedman et al., 1990). This may be the explanation for the significantly higher amount of fat mass in postmenopausal females in the present study.

The increase of estrogen levels during late childhood and puberty seems to promote not only the onset of the first menstrual bleeding but also the development of a higher amount of body fat tissue. This connection persists during adolescence and adulthood and even after menopause. The higher amount of body fat, which acts as a secondary hormonal gland, influences estrogen levels during the whole of adult life (Longscope, 1979; Longscope et al., 1980; Cleland et al., 1985). Therefore, significant relationships exist between age at menarche and body fat development also long after the end of puberty. It is worth noting that we could not document the impact of menarcheal age on adult body fat distribution that had been reported by Frisancho and Flegel (1982).

The low number of statistically significant relations between the onset of menarche and body fat in postmenopausal females is concordant with the results of Ness (1991), who interpreted these differences between pre- and postmenopausal females as reflecting the limitation of the retrospective method and differential memory loss. Ness (1991) also considered the decrease of correlation coefficients between weight during childhood and weight during adulthood with increasing chronological age. However, the menopausal transition induces several marked changes in the kind of body fat distribution and the amount of body fat. The fat mass increases in general, and body fat distribution changes from the gynoid type of fat distribution, typical of the fertile phase of life, to the android type of fat distribution, typically found in postmenopausal women and in males throughout life (Skerlj, 1960; Aloysio et al., 1988; Dawson-Hughes and Harris, 1992; Ley et al., 1992). Kirchengast (1993) noted that the fewer significant correlations between menarcheal age and body fat parameters in postmenopausal women than in premenopausal women may be due to hormonal and body composition changes during menopause such as are described above. The hormonal changes which accompany menopause transition may influence postmenopausal body fat development independently from that which was produced

during childhood and early puberty. Such influence would diminish the a priori relationships.

Various factors such as ethnicity (Beall and Goldstein, 1992; Kumanyika, 1994; Conway, 1995) or socioeconomic parameters (Van Itallie, 1985; Garn, 1986; Garn et al., 1989) influence body composition in premenopausal as well as postmenopausal women. Poor and impoverished women tend to be fatter and more often obese, while women of high socioeconomic status tend to be leaner. In the present study group differences in body composition cannot be explained by ethnic or social differences between the probands. All probands were Caucasians and stem from Vienna, the most urbanized region of Austria. Furthermore, all probands regardless of their menopausal status belong to the middle class, as defined by educational level, profession, husband's profession, and place of residence. These factors were constant between pre- and postmenopausal probands, though differences occurred in martial status: while 95% of the postmenopausal women were married, divorced, or widowed, 36% of the premenopausal women were still unmarried. All probands are representative of urban middle class women in Austria. Since no significant socioeconomic differences exist between our probands, body composition differences between early, moderate, and late maturers cannot be explained by socioeconomic differences.

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